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Evolution of the entrance rate and of the spatio-temporal distribution of Lessepsian Mollusca in the Mediterranean Sea

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The evolution of the entrance rate of Lessepsian Mollusca into the Mediterranean Sea as well as the development of their spatio-temporal dispersal were investigated, based on literature data and intensive sampling, off the coasts of Cyprus, SW Turkey and the Aegean coasts of Greece and Turkey. Based on our results, 130 species of Mollusca (1 species of Polyplacophora, 84 species of Gastropoda, 41 species of Bivalvia and 4 species of Cephalopoda) can be considered as verified Lessepsian migrants. Analysis of data revealed that there is an acceleration of the entrance rate of Lessepsian molluscs (similar pattern with Lessepsian Decapoda), which is statistically significant. Furthermore, there is a progressive dispersal of Lessepsian molluscs from Port Said to the west, along the African coast, and to the east along the coasts of Israel, Lebanon, and Syria, from there towards the southern Turkish coasts and the coasts of Cyprus, and finally towards the Greek and Turkish Aegean coasts. The increasing trend in the entrance rate of thermophilous Lessepsian Mollusca as well as their progressive dispersal towards higher latitudes could be attributed to the observed, gradual increase in temperature of the Mediterranean waters.

Key words: Lessepsian migration, Mollusca, Mediterranean Sea.

INTRODUCTION

The first review of the phenomenon of Lessepsian migration was given by Por (1978). In his review, he reported 44 species of Lessepsian Mollusca (27 of high and 17 of low probability) and provided information on their distribution in the Mediterranean Sea. According to Por (1978), Lessespian molluscs are shallow-water species of Indo-Pacific origin which have actively entered the Mediterranean after successfully colonizing the Suez Canal.

Later, Por & Dimentman (2006) provided an updated review of the Lessepsian migration refuting certain of the views set forth by Por (1978). These authors noted that Lessepsian migration is a duplication of a natural and active process of species area expansion. Hence, species of Indo-Pacific origin which are newly recorded in the Mediterranean Basin but have most probably been transported passively by human navigational means or by aquaculture should not be treated as "true" Lessepsian migrants, but rather as introduced non-indigenous species.

Since the review of Por (1978) a significant amount of information has been published on Lessepsian Mollusca (e.g. Barash & Danin, 1982, 1986; van Aartsen *et al.*, 1989, 1990; Koutsoubas, 1992; Buzzurro & Greppi, 1995, 1996; Koutsoubas & Cinelli, 1996; Zenetos *et al.*, 2003, 2005, 2009a,b,c, 2011; Mienis, 2004a, 2008; Galil, 2006, 2009; Koutsoubas *et al.*, 2007; Katsanevakis *et al.*, 2009). Galil (2006), reviewing the erythrean invasion, listed 139 species of Lessepsian Mollusca in the Mediterranean Sea. Three years later, Galil (2009) listed 175 molluscs of Indo-Pacific origin in the Mediterranean. However, 46 of these should not be considered Lessepsian migrants,

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since they were introduced in the Mediterranean by maritime transportation.

The review of the relevant literature shows that although there is a significant amount of data on the geographical distribution of Lessepsian molluscs, there is no information on their entrance rate in the Mediterranean or the evolution of their spatio-temporal dispersal. Por (1978) treating all Lessepsian groups as one heterogeneous unit, noted that there were no indications at that time that the Lessepsian migration had been speeding up and the processes seemed to tend to an asymptotic equilibrium. Recently, Por & Dimentman (2006) noted that the previous assumption of Por (1978) had not been proved correct after a quarter of a century.

On the other hand, there is now evidence that during the last 80 years, the entrance rate of different Lessepsian groups in the Mediterranean is accelerating. Tzomos *et al.* (2007) and Ben Rais Lasram & Mouillot (2009) have clearly demonstrated that there is an increase in the entrance rate of Lessepsian fish in the Mediterranean while there is also a gradual dispersal of these species towards higher geographical latitudes. Also, Koukouras *et al.* (2010) have reached similar results in respect to Lessepsian Decapoda. The accelerating entrance rates of these Lessepsian groups as well as their significant dispersal have been linked with the gradual increase in the temperature of the Mediterranean waters, a phenomenon reflecting the ongoing climate change (Béthoux *et al.*, 1990; Boero *et al.*, 2008; Ben Rais Lasram & Mouillot, 2009).

The aims of this study were: (i) to quantify the entrance rate of Lessepsian Mollusca into the Mediterranean Sea, (ii) to reveal a possible pattern in the spatio-temporal dispersal of these species in the Mediterranean Sea, and (iii) to identify potential factors that determine the intensity of the entrance rate and the dispersal of the species of Lessepsian molluscs.

MATERIALS AND METHODS

In order to gather more data on the Lessepsian molluscs, a suitable network of sampling stations was designed focusing on areas of inadequate sampling. The locations of the 25 sampling stations selected are given in Figure 1. Sampling was carried out during 2004 and 2005, with all available sampling gear (trawl nets, hanging nets, fishing traps, free diving and SCUBA diving) depending on the type of habitat.

In order to perform the spatial analysis of the data collected, the following five geographical areas, situated on the Lessepsian migration routes were determined: 1, PS (Port Said up to the Syrian-Turkish border); 2, ST (southern Turkish coast, west of the Syrian-Turkish border to the Gulf of Fethiye); 3, CY (Cyprus); 4, AS (Greek and Turkish Aegean Sea coasts, north of Fethiye Gulf) and 5, NA (North African coast). Moreover, we investigated the spatio-temporal dispersal of Lessepsian Mollusca towards the Central Mediterranean (CM, delimited to west by the Strait of Sicily and to the east by Crete Island, excluding the northern African coast), the Adriatic Sea (AD, north of the Strait of Otranto) and the West Mediterranean (WM, west of the Strait of Sicily).

Based on the literature collected and the sampling data obtained, Table 1 was constructed in which all verified species of Lessepsian Mollusca were included. In all estimates made, where possible, the year of collection of a species was considered instead of the year of publication of the relevant information.

For each one of the five designated areas of the eastern Mediterranean, the total number of species of Lessepsian Mollusca reported so far was estimated. Furthermore, the number of species in each area was estimated for two periods: from 1869 to 1990 and from 1990 onwards. The year 1990 was chosen as a cut-off point, since there were few records (only 8 species) of Lessepsian molluscs from the Aegean Sea before that year. Furthermore, the relevant sampling effort seems to be more intensive in all areas from that year onwards (see references in Table 1).

For estimating the annual, numerical accumulation of the Lessepsian molluscs, the period from 1954 to 2009 was chosen. It should be noted that prior to 1954, there were very few studies on the Lessepsian molluscs in the Mediterranean and thus the relevant data were not considered reliable to make estimates on the numerical accumulation of species. For the time period 1954-2009, the cumulative numbers of Lessepsian Mollusca were estimated per year and then plotted against time. The data thus compiled were assessed using regression analysis.

The entrance rate of Lessepsian Mollusca (number of new species per 15 years) was estimated for the period 1869 (opening of the Suez Canal) up to 2003. This period was divided into 9 consecutive 15-year intervals. For each of these, the number of new mollusc species that entered the Mediterranean via the Lessepsian route was calculated. The division into 15-year intervals was intended to decrease the high variation in the number of new Lessepsian molluscs per

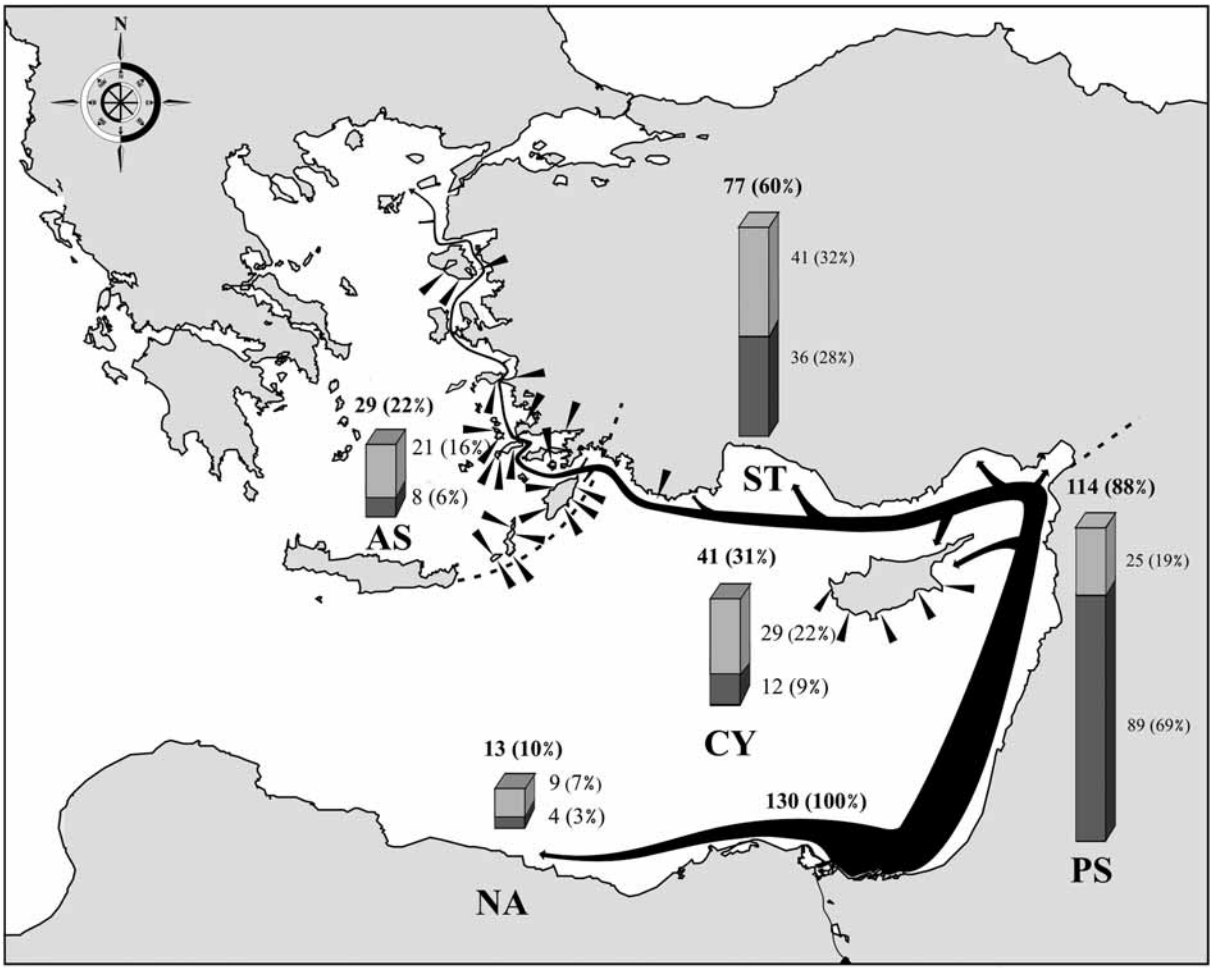

FIG. 1. The sampling locations during the present study indicated by black triangles. Geographical distribution of the Lessepsian Mollusca (in absolute numbers and in percentages of their total number) in the five areas here recognized, and for two time periods: 1869-1990 (lower, dark part of the column) and 1990-onwards (upper, light part of the column). The black, thinning zone and arrows show the probable route of the expansion of the Lessepsian molluscs. The thickness of the zone indicates the number of species. Abbreviations: PS: Port Said up to the Syrian-Turkish border; ST: southern Turkish coast; CY: Cyprus; AS: Greek and Turkish Aegean Sea coasts; NA: north African coast.

year, an obvious result of the different intensity in sampling efforts. The assessment of entrance rate over time was performed using regression analysis.

RESULTS

In total, 130 species of Mollusca (1 species of Polyplacophora, 84 species of Gastropoda, 41 species of Bivalvia and 4 species of Cephalopoda) can be considered as verified Lessepsian migrants. These species are given in Table 1, along with their distribution in the geographical areas of the Mediterranean as defined herein.

Figure 2 shows the annual numerical accumulation of Lessepsian Mollusca for the period 1954 to 2009. The linear regression trend (given by: $y = 1.9809x - 3846.3$) shows a statistically significant ($p < 0.001$) increase of their cumulative number per year. That is, every year, on average, approximately 2 Lessepsian mollusc species are entering the Mediterranean Sea.

Changes in the entrance rate of the Lessepsian Mollusca (number of new species per 15 years) for the period 1869 to 2003 are shown in Figure 3. The linear regression trend (given by: $y = 0.2922x - 553.68$) shows a statistically significant ($p < 0.001$) increase of the entrance rate in relation to time. That is, in every consecutive fifteen-year interval the number of new Lessepsian mollusc species entering the Mediterranean is on average higher than the previous fifteen-year interval.

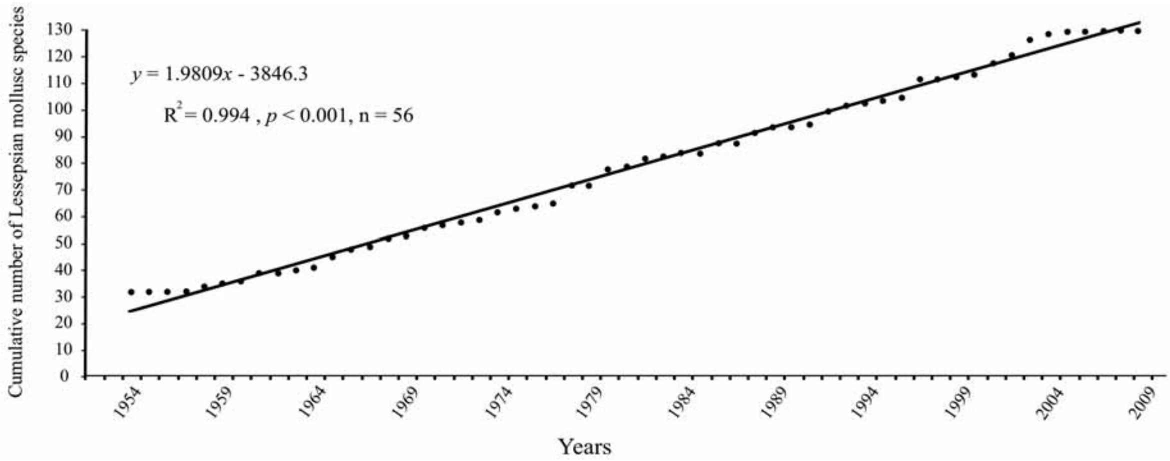

FIG. 2. Annual numerical accumulation of Lessepsian Mollusca from 1954 up to 2009.

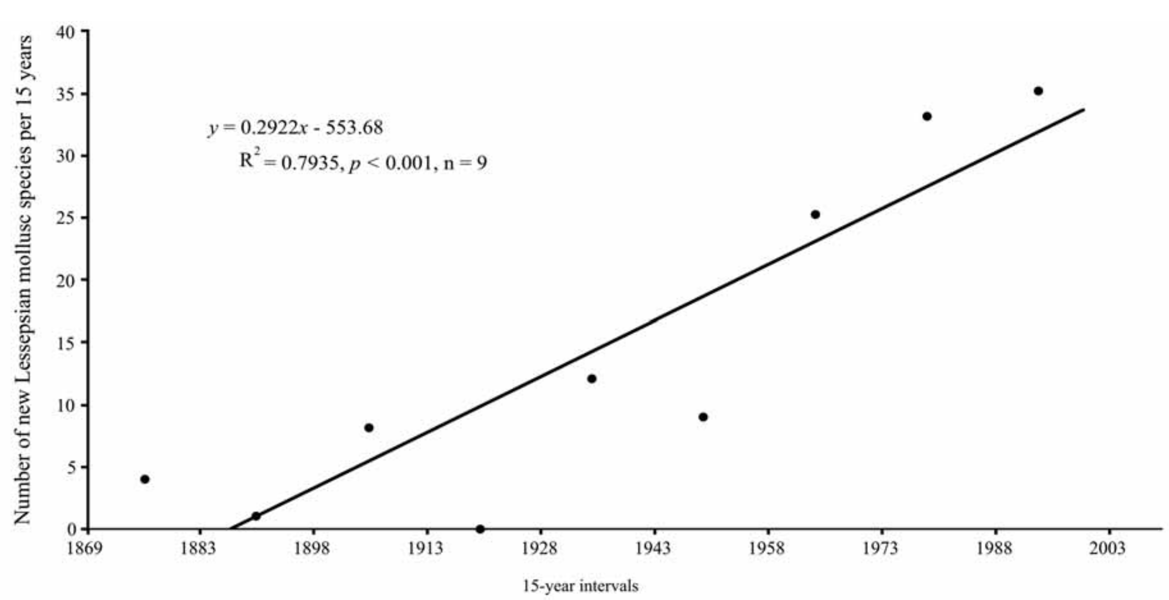

FIG. 3. Change of the entrance rate (number of new species per fifteen years) in the nine consecutive fifteen-year intervals for the period 1869-2003.

The annual numerical accumulation of the number of Lessepsian Mollusca in five geographical areas of the eastern Mediterranean and in the Mediterranean as a whole is shown in Figure 4. Area PS, the area closest to Port Said, hosts the highest number of species (114), and their presence has been reported starting 1874, that is 5 years after the opening of the Suez Canal. Area NA, to the west of Port Said and directly neighboring as well, hosts a much lower number of species (13) reported from 1869 onwards. The area ST beyond PS, hosts less species (77) than the latter. Moreover, the presence of these species was not reported before 1958. Cyprus (CY), geographically isolated and separated from the neighboring mainland, hosts a lower number of Lessepsian Mollusca than area ST (41 species) and their presence has been reported starting in 1899. Finally, the Greek and Turkish Aegean Sea coasts (AS) host the lowest number of Lessepsian species (29) with the exception of NA, while recording Lessepsian molluscs has started there in 1939.

Based on the above, it is apparent that the time required for the dispersal of Lessepsian molluscs from Port Said towards the five geographical areas is related to the shoreline distance of the areas from Port Said. Thus, in areas located further away, the ac-

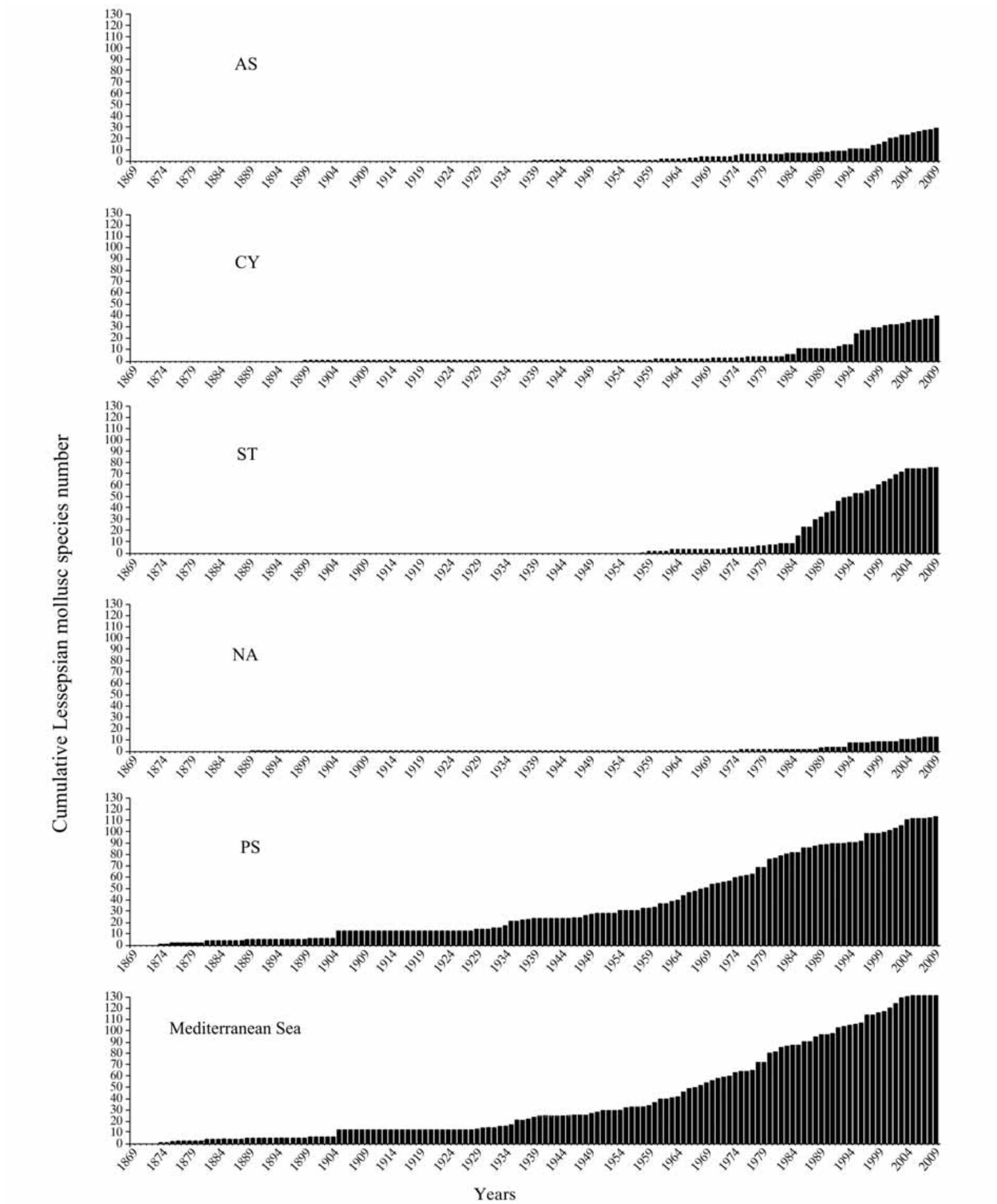

FIG. 4. Annual numerical accumulation of Lessepsian Mollusca in the five geographical areas here recognized, and also in the Mediterranean Sea as a whole. Abbreviations as in Figure 1.

cess of Lessepsian molluscs is happening with an analogous time delay. Minor deviations from this pattern should be attributed to the different intensity of the sampling effort carried out in each area.

Figure 1 demonstrates the distribution of the Lessepsian Mollusca in the five designated geographical areas of the eastern Mediterranean. As demonstrated, the total number of known species is decreasing from

TABLE 1. Lessepsian mollusc species in the Mediterranean and their distribution in the five designated eastern Mediterranean areas, the Adriatic Sea, the central, and the western Mediterranean. For each species, the first collection year for each area is given as well as relevant literature references. Abbreviations: PS: Port Said up to the Syrian-Turkish border; ST: southern Turkish coast; CY: Cyprus; AS: Greek and Turkish Aegean Sea coasts; NA: north African coast; AD: Adriatic Sea; CM: central Mediterranean (excluding the northern African coast); WM: western Mediterranean; *: species collected during the present study

	PS	ST	CY	AS	NA	AD	CM	WM	References
POLYPLACOPHORA									
Chiton hululensis (E.A. Smith in Gardiner, 1903)	1934								Barash (1973)
GASTROPODA									
Acteocina crithodes Melvill & Standen, 1907		2003							Mienis (2004a)
Acteocina mucronata (Philippi, 1849)	1986	1986	1992	1991	1989				Zenetos *et al.* (2003)
Amathina tricarinata (Linnaeus, 1767)	2000	2000							Çeviker & Albayrak (2006)
Angiola punctostriata (E.A. Smith, 1872)	1950								Mienis (1980a)
Atys cylindricus (Helbling, 1779)	2002								Mienis (2004a)
Bulla arabica Malaquias & Reid, 2008	1978	1992	2000	1998	2007				Zenetos *et al.* (2003, 2011)
Caloria indica (Bergh, 1896)	1986								Gat (1993)
Cellana rota (Gmelin, 1791)	1961			1989					Zenetos *et al.* (2003, 2009c)
Cerithidium diplax (Watson, 1886)	1961	1986							van Aartsen (2006)
Cerithidium perparvulum (Watson, 1886)	2004	1986	1995						van Aartsen (2006)
Cerithiopsis pulvis (Issel, 1869)	1978	1989	1985						Zenetos *et al.* (2003)
Cerithiopsis tenthrenois (Melvill, 1896)	1982	<1990	1985						Zenetos *et al.* (2003)
Cerithium columna Soweby, 1834	1996								Mienis (2003a)
Cerithium egenum Gould, 1849	1971								Mienis (2001a)
Cerithium nesioticum Pilsbry & Vanatta, 1906	1970		1985						Zenetos *et al.* (2003)
**Cerithium scabridum* Philippi, 1848	1882	1985	1983	1998	1997		<1978	1976	Tzomos (2007), Zenetos *et al.* (2009b), Antit *et al.* (2011)
Chelidonura fulvipunctata Baba, 1938	1986	1959					1993		Zenetos *et al.* (2003)
Chromodoris annulata Eliot, 1904	2009	2008	2009	2003					Gökoğlu & Özgür (2008), Zenetos *et al.* (2011)
Chromodoris quadricolor (Rüppell & Leuckart, 1830)		2004			2003			1982	Öztürk & Can (2006)
Chrysallida fischeri (Hornung & Mermod, 1925)	1974	1988				1993			Zenetos *et al.* (2003)
Chrysallida maiae (Hornung & Mermod, 1924)	1935	1963	1995						Zenetos *et al.* (2003)
Chrysallida micronana Öztürk & van Aartsen, 2006		1997		2000					Öztürk & van Aartsen (2006)
Chrysallida pirinthella (Melvill, 1910)	1982	1988							Zenetos *et al.* (2003)
Cingulina isseli (Tryon, 1886)	1980	1986	1998						Zenetos *et al.* (2003)
Clypeomorus bifasciatus (Sowerby G.B II, 1855)	1983				1994				Zenetos *et al.* (2003)
Cycloscala hyalina (Sowerby G.B. II, 1844)		1995	1992						Zenetos *et al.* (2003)

TABLE 1. continued

	PS	ST	CY	AS	NA	AD	CM	WM	References
Cylichnina girardi (Audouin, 1826)	1974	1990	1996	1994					Zenetos *et al.* (2003)
Dendrodoris fumata (Rüppell & Leuckart, 1830)	1980								Barash & Danin (1986)
Diala varia A. Adams, 1861	1935	2002							Zenetos *et al.* (2003)
Diodora ruppellii (Sowerby G.B. I, 1835)	<1948	1985							Galil (2009)
Engina mendicaria (Linnaeus, 1758)	2001								Mienis (2004a)
Ergalatax contracta (Reeve, 1846)	2001								Mienis (2004a)
Ergalatax junionae Houart 2008	2004	1992	1993	2002					Zenetos *et al.* (2008)
Erosaria turdus (Lamarck, 1810)	1980				2003		2005		Galil (2009)
Finella pupoides A. Adams, 1860	1958	1958	<1996	2001					Öztürk & Can (2006)
Flabellina rubrolineata (O'Donoghue, 1929)	1988	2001	2003						Zenetos *et al.* (2003)
Fusinus verrucosus (Gmelin, 1791)	1882								Zenetos *et al.* (2003)
Gibborissoa virgata (Philippi, 1849)	1970	1997							van Aartsen (2002)
Haliotis pustulata cruenta Reeve, 1846	1961				1994				Zenetos *et al.* (2003)
Haminoea cyanomarginata Heller & Thompson, 1983		2002		2001			2006		Crocetta & Vazzana (2008)
Hinemoa cylindrica (de Folin, 1879)		1992							Buzzurro *et al.* (2001)
Hypselodoris infucata (Rüppell & Leuckart, 1830)	1965	1999							Özvarol *et al.* (2010)
Leucotina eva Thiele, 1925		1995		2000					Çinar *et al.* (2011)
Leucotina natalensis Smith E.A. 1910	1978	1986	<1996						Galil (2009)
Lienardia mighelsi Iredale & Tomlin, 1917				<2003					Cinar *et al.* (2005)
Metaxia bacillum (Issel, 1869)	1978	1992	<1995						Zenetos *et al.* (2003)
Monotigma lauta (A. Adams, 1853)	1967	1988							Galil (2009)
Murchisonella columna (Hedley, 1907)	1997	1993							Zenetos *et al.* (2003)
Murex forskoehlii Röding, 1798	<1905			1966					Settepassi (1967)
Nassarius arcularia pilcatus (Röding, 1798)	1968								Barash & Danin (1977)
Nerita sanguinolenta Menke, 1829		2004		1968	1994				Zenetos *et al.* (2003), Mutaf *et al.* (2007)
Notocochlis gualteriana (Récluz, 1844)	1966						1996		Galil (2009)
Odostomia lorioli (Hornung & Mermod, 1924)	1974								van Aartsen (1987)
Oscilla jocosa Melvill, 1904	1984								van Aartsen *et al.* (1989)
Oxynoe viridis (Pease, 1861)		2002							Galil (2009)
Palmadusta lentiginosa (Gray, 1825)	1989								Mienis (1990)
Planaxis savignyi Deshayes 1844	<1905								Galil (2009)
Pleurobranchus forskalii Rüppell & Leuckart, 1828	1975								Barash & Danin (1977)
Plocamopherus ocellatus Rüppell & Leuckart, 1828	1977	1998							Yokes & Rudman (2004)

TABLE 1. continued

	PS	ST	CY	AS	NA	AD	CM	WM	References
Pseudominolia nedyma (Melvill, 1897)	1966	1992							Zenetos *et al.* (2003)
Purpuradusta gracilis notata (Gill, 1858)	1981	1982	2000						Zenetos *et al.* (2009a)
Pyrunculus fourierii (Audouin, 1826)	1986	<1989	1995						Galil (2009)
Retusa desgenettii (Audouin, 1826)	1969								Mienis (2004b)
Rhinoclavis kochi (Philippi, 1848)	1963	1985	1976		1975				Galil (2009)
Rhinoclavis sinensis (Gmelin, 1791)	2003								Mienis (2004a)
Rissoina ambigua (Gould, 1849)		2003							Mienis (2004a)
Rissoina bertholleti Issel, 1869	1958	1985	1985						Zenetos *et al.* (2003)
Rissoina spirata Sowerby G.B. I, 1820	<1997								Giannuzzi-Savelli *et al.* (1997)
Sabia conica (Schumacher, 1817)	1954							1990	Barash & Danin (1986)
Siphonaria crenata de Blainville, 1827	1965	1999							Zenetos *et al.* (2003)
Smaragdia souverbiana (Montrouzier, 1863)		1992	1995						Zenetos *et al.* (2003)
Sticteulima lentiginosa (A. Adams, 1861)	2004	1989	1995						Galil (2009)
Stomatella impertusa (Burrow, 1815)		1999							Zenetos *et al.* (2003)
Strombus mutabilis Swainson, 1821	1991								Mienis (2001b)
**Strombus persicus* Swainson, 1821	1983	1978	1985	1983	2006	1996			Ben Souissi & Zaouali (2007), Tzomos (2007)
Syrnola cinctella A. Adams, 1860		1994							van Aartsen & Recevik (1998)
Syrnola fasciata Jickeli, 1882	1949	1963	1995	2001					Öztürk & Can (2006)
Syrnola lendix (A. Adams, 1863)	1994	1988							Galil (2009)
**Trochus erithreus* Brocchi, 1821	1968	1992	1985	1994					Tzomos (2007)
Turbonilla edgarii (Melvill, 1896)	1980	1988	1996						Zenetos *et al.* (2003)
Vexillum depexum (Deshayes in Laborde, 1834)	1964								Mienis (2004c)
Voorwindia tiberiana (Issel, 1869)	1997								Giannuzzi-Savelli *et al.* (1997)
Zafra savignyi (Moazzo, 1939)	1954	1986	1995						Zenetos *et al.* (2003)
Zafra selasphora (Melvill & Standen, 1901)	1980	1993	1995						Zenetos *et al.* (2003), Çinar *et al.* (2011)
BIVALVIA									
Afrocardium richardi (Audouin, 1826)	1997	2000							Zenetos *et al.* (2003)
Alectryonella crenulifera (Sowerby G.B. II, 1871)	2005								Sharon *et al.* (2005)
Anadara natalensis (Krauss, 1848)	1935	1985							Zenetos *et al.* (2003)
Angulus flacca (Roemer, 1871)	1997								Mienis (2004a)
Antigona lamellaris Schumacher, 1817		1988							Engl & Çeviker (1999)
Atactodea glabrata (Gmelin, 1791)	1973						1977		Barash & Danin (1977), Cachia *et al.* (2004)

TABLE 1. continued

	PS	ST	CY	AS	NA	AD	CM	WM	References
**Barbatia plicata* (Dillwyn, 1817)	1978	2004							Tzomos *et al.* (2010)
**Brachidontes pharaonis* (P. Fischer, 1870)	1876	1978	1960	1975		2005	1969	<1971	Zenetos *et al.* (2003, 2009c)
Callista florida (Lamarck, 1818)	1932								Galil (2009)
Chama aspersa Reeve, 1846	2002	1993	2007	2006					Ovalis & Zenetos (2007), Manousis *et al.* (2010)
Chama pacifica Broderip, 1834	<1905	2000	1998	2005					Zenetos *et al.* (2003), Manousis *et al.* (2010)
Circenita callipyga (von Born, 1778)	1972								Zenetos *et al.* (2011)
Clementia papyracea (Gray, 1825)	1937	1985							Zenetos *et al.* (2003)
Diplodonta bogii van Aartsen, 2004	1982			2008					Zenetos *et al.* (2003), Manousis *et al.* (2010)
Divalinga arabica Dekker & Goud, 1994	1976								Barash & Danin (1986)
Dosinia erythraea Roemer, 1860	<1905			2007					Zenetos *et al.* (2003), Manousis *et al.* (2010)
Fulvia australis (Sowerby G.B. II, 1834)	<1948								Haas (1948)
Fulvia fragilis (Forsskål, 1775)	1938	1986	1983	1998	1990		2008	1991	Zenetos *et al.* (2009a, 2009c)
Gafrarium pectinatum (Linnaeus, 1758)	<1905	1986	2005						Zenetos *et al.* (2009a)
Gastrochaena cymbium Spengler, 1783	1954	1990		1974					Zenetos *et al.* (2003), Manousis *et al.* (2010)
Glycymeris arabica (H. Adams, 1870)	1966								Barash & Danin (1977)
Hiatula ruppelliana (Reeve, 1857)	<1905								Tillier & Bavay (1905)
Laternula anatina (Linnaeus, 1758)	<1905	1992							Zenetos *et al.* (2003)
Limopsis multistriata (Forsskål, 1775)	1965								Barash & Danin (1977)
Mactra lilacea Lamarck, 1818	1965								Mienis (2002)
Mactra olorina Philippi, 1846	<1889								Zenetos *et al.* (2003)
Malvufundus regulus (Forsskål, 1775)	<1929	1973	1970	1999	2001				Galil (2009), Zenetos *et al.* (2009c)
Modiolus auriculatus (Krauss, 1848)	1935								Haas (1937)
Musculista perfragilis (Dunker, 1857)	1960								Barash & Danin (1972)
Nanostrea exigua Harry, 1985	2004								Mienis (2008)
Paphia textile (Gmelin, 1791)	1939	1985	2004						Zenetos *et al.* (2009a)
Petricola hemprichi Issel, 1869	1900	1999							Çeviker & Albayrak (2006)
Pinctada radiata (Leach, 1814)	1874	1982	1899	1961	1890	<1996	1915	<1979	Zenetos *et al.* (2003)
Psammotreta praerupta (Salisbury, 1934)	2008	1992	2009						Zenetos *et al.* (2009a), Mienis (2010)

TABLE 1. continued

	PS	ST	CY	AS	NA	AD	CM	WM	References
Pseudochama corbieri (Jonas, 1846)	1963			1939					Zenetos *et al.* (2003), Manousis *et al.* (2010)
Septifer forskali Dunker, 1855		2001	2005	2010					Zenetos *et al.* (2009a, 2011)
Sphenia rueppellii A. Adams, 1850	1978	1998							Barash & Danin (1986), Zenetos *et al.* (2010)
Spondylus spinosus Schreibers, 1793	1988	1991	2001						Zenetos *et al.* (2009a)
Tellina valtonis Hanley, 1844	1970	1995							Zenetos *et al.* (2003)
Timoclea marica (Linnaeus, 1758)	1997								Bogi & Galil (1999)
Trapezium oblongum (Linnaeus, 1758)	1980								Mienis (1980b)
CEPHALOPODA									
Octopus aegina Gray, 1849	1934	1992							Salman *et al.* (1999)
Octopus cyanea Gray, 1849	1997								Mienis (2003b)
Sepia pharaonis Ehrenberg, 1831	2003								Mienis (2003c)
**Sepioteuthis lessoniana* Férussac, 1831 in Lesson, 1830-1831	2004	2002	2009	2009					Tzomos *et al.* (2010)

area PS (114) towards area ST (77) and CY (41 species) and then, towards AS (29) while the number of species recorded before 1990 (dark part of the column) is also decreasing in the same direction (PS, 89 species; ST, 36 species; CY, 12 species and, AS, 8 species). On the contrary, the number of species recorded from 1990 onwards is increasing from area PS (25 species) to areas, ST (41 species) and CY (29 species) while it shows a decrease towards area AS (21 species). Furthermore, most of the Lessepsian mollusc species recorded in areas, ST and CY after 1990 have been collected in area PS before 1990, whilst species reported in area AS after 1990 have been reported in area ST either before 1990 or some years before their collection in the Aegean Sea (Table 1).

In respect to area NA, thirteen species of Lessepsian Mollusca have been reported so far. Four of these species have been collected before 1990, while nine of them after 1990. In respect to the latter, they have been recorded from area PS before 1990.

DISCUSSION

A review of the relevant literature shows that the entrance rate of Lessepsian species in the Mediterranean has not been studied in detail. Por (1978) noted that there is no indication that the Lessepsian migration is speeding up while later, Por & Dimentman (2006) argued that there is no evidence that the migratory process is nearing a plateau without however, providing any other information. Madl (1999), considering all Lessepsian groups combined to a heterogeneous unit noted that the process of Lessepsian immigration will eventually reach a plateau but, according to the same author, there were no such indication at that time. He also estimated that the immigration continues at a rate of 5 to 10 species per year.

In respect to specific Lessepsian groups, Koukouras *et al.* (2010) showed that during the period 1869 to 2003, the entrance rate of Lessepsian decapods has been accelerating. Moreover, these authors estimated that during the period 1924 to 2007 the cumulative species number of Lessepsian decapods has been increasing on average by 0.39 species per year. Similarly, Ben Rais Lasram & Mouillot (2009) demonstrated that during the period 1910 to 2006 the entrance rate of Lessepsian fish has been increasing. Based on the results of these authors, during the 1990s, the average number of new Lessepsian fish entering the Mediterranean per annum was 0.7 species, while from 2000 onwards this number has increased to two species per annum.

Based on our results, the entrance rate of Lessepsian Mollusca in the Mediterranean is also accelerating. As it has been demonstrated for the period 1869 to 2003, the number of new Lessepsian mollusc species entering the Mediterranean per 15 years is on average increasing. Moreover, during the period 1954 to 2009, the cumulative number of Lessepsian Mollusca has been increasing, by 2 species per year on average. The apparent differences in the entrance rates among the Lessepsian Mollusca and the two other taxonomic groups studied (Ben Rais Lasram & Mouillot, 2009; Koukouras *et al.*, 2010) should probably be attributed to the differences in the mode of life of these taxonomic groups which clearly affect their dispersal capabilities (Por, 1978). Furthermore, these Lessepsian groups have not equally attracted the attention of scientists with the relevant research being more focused towards fish (Azzurro, 2008; Galil, 2009).

Although there are numerous published records on the presence of Lessepsian Mollusca in different areas of the eastern Mediterranean, this information has not been adequately analysed in order to acquire a detailed view on the current geographical distribution of these species and their spatio-temporal dispersal. Based on our results, there is a progressive expansion of the geographical distribution of Lessepsian Mollusca in the Mediterranean towards higher geographical latitudes. For example, 20 out of 21 mollusc species recorded in the Aegean Sea (area AS; Fig. 1) after 1990 have been previously recorded in areas ST and PS before 1990. Thus, these species have reached the Aegean Sea by expanding their geographical distribution towards the north. The increasing trend in the number of species recorded after 1990, along the Lessepsian route should mainly be attributed to the progressive dispersal of the species recorded before 1990. On the other hand, the decrease in the number of species in AS indicates that certain Lessepsian Mollusca have not yet reached the Aegean Sea. In general, the Lessepsian molluscs seem to be gradually expanding their distribution from Port Said both towards the west along the African coast, and towards the east along the coasts of Israel, Lebanon and Syria; from there, towards the southern Turkish coast and the coasts of Cyprus, and finally towards the Aegean Sea. Furthermore, four species have already reached the Adriatic Sea, nine have been collected from the Central Mediterranean (excluding the northern African coast), while six Lessepsian mollusc species have already reached the western part of the Mediterranean (Table 1). Most of the Lessepsian Mollusca are coastal species (Por, 1978; Zenetos *et al.*, 2003) and they expand their distribution moving in shallow waters along coastal areas. A similar pattern of dispersal has been also reported for other Lessepsian groups, such as fish (Tzomos *et al.*, 2007; Ben Rais Lasram & Mouillot, 2009) and decapods (Koukouras *et al.*, 2010).

In respect to the current geographical distribution of Lessepsian Mollusca in the Mediterranean and their spatio-temporal dispersal in the areas of the eastern Mediterranean we can note the following:

Area PS, the most proximate area to Port Said, hosts the highest number of Lessepsian molluscs (114 species) compared to any other of the areas studied. However, sixteen species of Lessepsian molluscs have not yet been reported from this area (Table 1). Two of these species have been reported from the North African coast (area NA), but close to Port Said. Moreover, fifteen of these species have been collected from the southern Turkish coast (area ST), two species were collected at Cyprus and 6 species at Aegean Sea. Thus, the lack of records of these sixteen species from area PS should probably be attributed to the lack of intensive sampling efforts in the Levantine coast (the Sinai Peninsula, Israeli and Lebanese coasts) as well as to the rarity of certain of these species.

The limited number of Lessepsian mollusc species (13) reported from area NA, should probably be attributed to adverse conditions prevailing in the area which interfere with the westward migration of Lessepsian species. Por (1978) argued that migration along the African coast has probably been delayed by the opposing currents, the structure of the outlet at Port Said and perhaps by the Nile water influx. Furthermore, the continuous, high intensity of hydrodynamism due to the long fetch of the North African coast to the prevailing NW winds (Nafaa *et al.*, 1991; Orme, 2005) should be considered another important, adverse factor. Moreover, the area west of Port Said is characterised by large areas of shallow soft substrata, composed of fine sediments originating from older sediment depositions from the Nile and recent subsidence of the delta coast (Orme, 2005). These fine sediments, combined with the high wave action, lead to the creation of large quantities of abioseston in the water column, while the substrate becomes unstable. These factors may also prohibit the westward dispersal of the Lessepsian Mollusca, which in their majority are benthic inhabitants.

Area ST hosts the highest number of Lessepsian Mollusca after area PS (77 species). It is interesting to note that 49 of these species have reached the southern Turkish coast by expanding their distribution from area PS (Table 1). The number of Lessepsian molluscs known from this area is expected to increase, since more species, already recorded in area PS, will eventually expand their distribution towards the southern Turkish coast, since the latter is a natural continuation of the former. Furthermore, the northward dispersal of the Lessepsian Mollusca along the eastern Levantine coast is probably facilitated by the northward stream that meanders along the coast and generates many eddies having a northward propagation (Alhammoud *et al.*, 2005). These eddies break down at the area of Latakia, east of Cyprus, providing an impulse flux to the Cilician current and to the Asia Minor current, which flow westwards along the southern Turkish coasts (Alhammoud *et al.*, 2005). These two currents seem to play an important role in the westward expansion of the Lessepsian Mollusca along the Anatolian coast.

Cyprus hosts a lower number of Lessepsian Mollusca (41 species) in relation to areas PS and ST. This should be mainly attributed to the isolation of the island from the neighbouring mainland by water masses of great depth which seems to be prohibitive for the arrival of Lessepsian molluscs; in their majority they are shallow-water species. This is also true for other islands in the Eastern Mediterranean such as the island of Crete (Koutsoubas *et al.*, 1992). Furthermore, in the south of Cyprus the temperature of surface waters is rather low as a result of upwelling driven by westerly winds (Alhammoud *et al.*, 2005). These low temperatures might also prevent the arrival of Lessepsian Mollusca, which are thermophilous species. Finally, the rather low number of species reported should also be attributed to the limited sampling effort that has been carried in the area.

The Aegean Sea (area AS) hosts 29 species of Lessepsian molluscs. This, rather low, number should be mainly attributed to the long distance of the Aegean Sea from Port Said, which results in a delayed arrival of Lessepsian species. The first Lessepsian mollusc species [*Pseudochama corbieri* (Jonas, 1846)] was collected at Saronikos Gulf in 1939 (Ralli-Tzelepi, 1946). Up to 1990, only eight Lessepsian molluscs (Table 1) have been reported from the area AS and most of these species were initially collected from the area of Rhodos Island (Barash & Danin, 1989; Zenetos *et al.*, 2003). However, during the last ten years certain species have significantly expanded their distribution northwards. In particular, two species of Lessepsian molluscs (*Finella pupoides* A. Adams, 1860 and *Syrnola fasciata* Jickeli, 1882) have expanded their distribution as northerly as Bodrum, at the Aegean coast of Turkey (Özturk & Can, 2006). Moreover, the bivalve, *Fulvia fragilis* (Forsskål, 1775) has expanded its distribution further north since it has been reported from the Gulf of Izmir (Özturk & Poutiers, 2005). Recently, Manousis *et al.* (2010) collected three species of Lessepsian bivalves (*Chama pacifica* Broderip, 1834; *Diplodonta bogi* van Aartsen, 2004 and, *Dosinia erythraea* Roemer, 1860) from Thermaikos Gulf (N. Aegean Sea) which are also new records for the Aegean Sea. Furthermore, they collected a single specimen of the bivalve *Diplodonta globosa* (Forsskål, 1775) which they characterize as a Lessepsian migrant. However, this species should be considered, at least for the time being, as a doubtful Lessepsian migrant, since it has not been previously recorded in the Mediterranean Sea. Furthermore, Manousis *et al.* (2010) reported two more species of Indo-Pacific origin from Thermaikos Gulf, *Cardites akabana* (Sturani, 1899) and *Chama asperella* Lamarck, 1819. *Cardites akabana* has been previously collected only from Iskederun Bay (southern coast of Turkey) by Çeviker & Albayrak (2006). These authors noted that this species has probably entered the Mediterranean by maritime transport. The bivalve *Chama asperella* has been previously reported from Ashqelon (coast of Israel) and from Saronikos Gulf (Aegean Sea, Greece) (Mienis, 2004a; Ovalis & Zenetos, 2007). However ship fouling is assumed as the most probable mode of introduction in the Mediterranean Sea (Ovalis & Zenetos, 2007). Based on the above data, these two species should also be considered as doubtful Lessepsian migrants and along with *Diplodonta globosa* were not included in Table 1 and our estimates.

According to Por (1978), during the present human-scale historical period the Lessepsian influence could be geographically confined only in the easternmost Mediterranean if drastic climatic changes were not bound to occur. It is now evident that the Mediterranean is becoming warmer as a reflection of the ongoing climate change. For the last decades, the temperature of the western Mediterranean has been rising in deep (Béthoux *et al.*, 1990) and surface waters (Diaz Almela *et al.*, 2007). A similar increase in the mean temperature of the waters of the eastern Mediterranean has also been documented (Raitsos *et al.*, 2010).

The observed increase in the mean temperature of the Mediterranean waters could be considered, at least for the time being, the major factor causing the estimated acceleration of the entrance rate of the Lessepsian Mollusca in the Mediterranean as well as their progressive dispersal towards higher geographical latitudes. Ben Rais Lasram & Mouillot (2009) have also demonstrated that for the period 1910 to 2006, there is a significant positive correlation between the number of newly reported Lessepsian fish per decade and the increasing mean decadal temperature of the Mediterranean waters. Furthermore, a significant amount of evidence has now been accumulated towards an ecological impact of the climate warming on the Mediterranean marine biota (Boero *et al.*, 2008). This evidence include the northward extension and enhancement of native thermophilic species (Francour *et al.*, 1994), the northward dispersal of Lessepsian and other non-indigenous species (Ben Rais Lasram & Mouillot, 2009; Koutsoubas *et al.*, 2009; Raitsos *et al.*, 2010) as well as mass mortality events (Bianchi & Morri, 2000; Cerrano *et al.*, 2000; Bianchi, 2007; Boero *et al.*, 2008).

Based on the existing data, predictions for the future development of the entrance rate of Lessepsian species do not seem to be feasible. This is mainly due to the lack of information on the exact mechanisms that drive this phenomenon. Lessepsian migration is a multifactorial and dynamic process in both space and time.

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REFERENCES

Alhammoud B, Béranger K, Mortier L, Crépon M, Dekeyser I, 2005. Surface circulation of the Levantine Basin: Comparison of model results with observations. *Progress in Oceanography*, 66: 299-320.

Antit M, Gofas S, Salas C, Azzouna A, 2011. One hundred years after *Pinctada*: an update on alien Mollusca in Tunisia. *Mediterranean Marine Science*, 12: 53-73.

Azzurro E, 2008. The advance of thermophilic species in the Mediterranean Sea: overview and methodological questions. In: Briand F, ed. *Climate warming and relat-*

ed changes in Mediterranean marine biota. CIESM Publishers, Monaco: 39-46.

Barash A, 1973. Polyplacophora (Mollusca) in the Eastern Mediterranean. *Israel Journal of Zoology*, 22: 203-204.

Barash A, Danin Z, 1972. The Indo-Pacific species of Mollusca in the Mediterranean and notes on a collection from the Suez Canal. *Israel Journal of Zoology*, 21: 301-374.

Barash A, Danin Z, 1977. Additions to the knowledge of Indo-Pacific Mollusca in the Mediterranean. *Conchiglia*, 13: 85-116.

Barash A, Danin Z, 1982. Mediterranean Mollusca of Israel and Sinai: composition and distribution. *Israel Journal of Zoology*, 31: 86-118.

Barash A, Danin Z, 1986. Further additions to the knowledge of Indo-Pacific Mollusca in the Mediterranean Sea (Lessepsian migrants). *Spixiana*, 9: 117-141.

Barash A, Danin Z, 1989. Marine mollusca at Rhodes. *Israel Journal of Zoology*, 35: 1-74.

Ben Rais Lasram F, Mouillot D, 2009. Increasing southern invasion enhances congruence between endemic and exotic fish fauna. *Biological Invasions*, 11: 697-711.

Ben Souissi J, Zaouali J, 2007. Sur la présence de nouvelles espèces exotiques dans la grande et la petite Syrte. *Rapport Commission Internationale Mer Méditerranée*, 38: 435.

Béthoux JP, Gentili B, Raunet J, Tailliez D, 1990. Warming trend in the Western Mediterranean deep water. *Nature*, 347: 660-662.

Bianchi CN, 2007. Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia*, 580: 7-21.

Bianchi CN, Morri C, 2000. Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. *Marine Pollution Bulletin*, 40: 367-376.

Boero F, Féral JP, Azzurro E, Cardin V, Riedel B, Despalatović M, Munda I, Moschella P, Zaouali J, Fonda Umani S, Theocharis A, Wiltshire K, Briand F, 2008. Climate warming and related changes in Mediterranean marine biota. In: Briand F, ed. *Climate warming and related changes in Mediterranean marine biota.* CIESM Publishers, Monaco: 5-21.

Bogi C, Galil BS, 1999. Nuovi ritrovamenti di immigranti lessepsiani lungo le coste israeliane. *La Conchiglia*, 31: 22-29.

Buzzurro G, Greppi E, 1995. Note sul materiale tipico di origine lessepsiana della collezione Hornung, Mermod. *Notiziario del CISMA*, 17: 5-16.

Buzzurro G, Greppi E, 1996. I Molluschi lessepsiani di Tasuçu (Turchia Meri-dionale). *La Conchiglia*, 28: 3-22.

Buzzurro G, Hoarau A, Greppi E, Pelorce J, 2001. Prima segnalazione di *Hinemoa cylindrica* (de Folin, 1879) per il Mediterraneo. *Bollettino Malacologico*, 37: 23-26.

Cachia C, Mifsud C, Sammut PM, 2004. *The Marine Mollusca of the Maltese Islands, Part 4: The Classes Caudofoveata Solenogastres, Bivalvia, Scaphopoda and Cephalopoda.* Backhuys Publishers, Leiden, The Netherlands.

Cerrano C, Bavestrello G, Bianchi CN, Cattaneo-vietti R, Bava S, Morganti C, Morri C, Picco P, Sara G, Schiaparelli S, Siccardi A, Sponga F, 2000. A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (north-western Mediterranean), summer 1999. *Ecology Letters*, 3: 284-293.

Çeviker D, Albayrak S, 2006. Three alien molluscs from Iskenderun Bay (SE Turkey). *Aquatic Invasions*, 1: 76-79.

Çinar ME, Bilecenoğlu M, Öztürk B, Katagan T, Aysel V, 2005. Alien species on the coasts of Turkey. *Mediterranean Marine Science*, 6: 119-146.

Çinar ME, Bilecenoğlu M, Öztürk B, Katagan T, Yokes MB, Aysel V, Dagli E, Acik S, Özcan T, Eedogan H, 2011. An updated review of alien species on the coasts of Turkey. *Mediterranean Marine Science*, 12: 257-316.

Crocetta F, Vazzana A, 2008. First record of *Haminoea cyanomarginata* (Gastropoda: Haminoeidae) in the Italian Seas. *JMBA2 – Biodiversity Records*: 6046.

Diaz-Almela E, Marbà N, Duarte CM, 2007. Consequences of Mediterranean warming events in seagrass (*Posidonia oceanica*) flowering records. *Global Change Biology*, 13: 224-235.

Engl W, Çeviker D, 1999. New migrant species from southeast Turkey *Psam-motreta praerupta* (Salisbury, 1934) and *Antigona lamellaris* Schumacher, 1817. *La Conchiglia*, 31: 17-20.

Francour P, Boudouresque CF, Harmelin JG, Harmelin-Vivien ML, Quignard JP, 1994. Are the Mediterranean waters becoming warmer? Information from biological indicators. *Marine Pollution Bulletin*, 28: 523-526.

Galil B, 2006. The marine caravan – The Suez Canal and the Erythrean invasion. In: Gollasch S, Galil B, Cohen N, eds. *Bridging divides, maritime canals as invasion corridors.* Springer-Verlag, The Netherlands: 207-300.

Galil BS, 2009. Taking stock: inventory of alien species in the Mediterranean sea. *Biological Invasions*, 11: 359-372.

Gat G, 1993. *Flabellina rubrolineata* (O' Donoghue) and *Phidiana indica* (Bergh) (Nudibranchia, Aeolidioidea), two new Lessepsian immigrants in the Eastern Mediterranean. *Journal of Molluscan Studies*, 59: 120.

Giannuzzi-Savelli R, Pusateri F, Palmeri A, Ebreo C, 1997. Atlante delle con-chiglie marine del mediterraneo. Vol. 2: Caenogastropoda. *La Conchiglia*, *Roma*, 1-258.

Gökoğlu M, Özgür E, 2008. First report of *Chromodoris annulata* Eliot, 1904 (Mollusca, Opisthobranchia, Chromodorididae) on the Levantine coast of Turkey, Eastern Mediterranean. *Aquatic Invasions* 3: 435-437.

Haas G, 1937. Mollusca marina. In: Bodenheimer FS, ed. *Prodromus faunae Palestinae, Essai sur les éléments zoogéographiques et historiques du sud-ouest du sous-règne Paléarctique*. Mémoires présentés à l'Institut d'Egypte: 275-280.

Haas G, 1948. Sur l' immigration de mollusques de l' Indo-Pacifique dans les eaux cô-tières de la Palestine. *Journal de Conchyliologie*, 88: 141-144.

Katsanevakis S, Tsiamis K, Ioannou G, Michailidis N, Zenetos A, 2009. Inventory of alien marine species of Cyprus (2009). *Mediterranean Marine Science*, 10: 109-133.

Koukouras A, Kitsos M-S, Tzomos Th, Tselepides A, 2010. Evolution of the entrance rate and the spatio-temporal distribution of Lessepsian Crustacea Decapoda in the Mediterranean Sea. *Crustaceana*, 83: 1409-1430.

Koutsoubas D, 1992. Contribution to the study of the gastropod molluscs of the continental shelf of the North Aegean Sea. Ph. D. thesis, Aristotle University of Thessaloniki, Greece.

Koutsoubas D, Cinelli F, 1996. Indo-Pacific origin gastropod species in the Aegean Sea: *Melibe fimbriata* Alder & Hancock, 1864, a new invader. *Bolletino Malacologico*, 32: 35-40.

Koutsoubas D, Koukouras A, Karakassis I, Dounas C, 1992. Contribution to the knowledge of Gastropoda and Bivalvia (Mollusca) of Crete Island (S. Aegean Sea). *Bolletino Malacologico*, 28: 69-82.

Koutsoubas D, Batzakas J, Sini M I, Poursanidis D, 2007. Exotic species in the NE Aegean Sea: *Lagocephalus sceleratus* (Gmelin, 1789) a new Lessepsian immigrant. *Proceedings of the 13th Hellenic Conference of Ichthyologists, Mytilini, Greece*: 4.

Koutsoubas D, Zervakis V, Tragou E, Poursanidis D, Zenetos A, 2009. Assessment of a possible relation between the variability of environmental parameters and the dispersion of invasive molluscs in the Hellenic Seas. *ASLO Aquatic Sciences Meeting, 25-30 January, Nice, France*: 140.

Madl P, 1999. Essay about the phenomenon of Lessepsian migration. *Colloquial Meeting of Marine Biology I, April 1999, Salzburg,* (revised in November 2001). http://www.sbg.ac.at/ipk/avstudio/pierofun/lm/lesseps.htm.

Manousis T, Mpardakis G, Paraskevopoulos C, Galinou-Mitsoudi S, 2010. The Bivalvia Mollusca of Thessaloniki & Thermaikos Gulfs (North Aegean Sea, Greece) with emphasis on new species for Hellenic waters. *Journal of Biological Research-Thessaloniki*, 14: 161-179.

Mienis HK, 1980a. *Planaxis lineolatus* Gould. Another Indo-Pacific species from the Mediterranean coast of Israel. *Levantina*, 28: 324.

Mienis HK, 1980b. A record of the Indo-Pacific species *Trapezium oblongum* from the Mediterranean coast of Israel. *Levantina*, 27: 313-314.

Mienis HK, 1990. *Cypraea lentiginosa*: Another odd record of an exotic cowry from the Mediterranean coast of Israel. *De Kreukel*, 26: 119-121.

Mienis HK, 2001a. Mariene Mollusken uit het Oostelijk deel van de Middellandse zee. 6. De eerste vondsten van *Cerithium egenum. Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 323: 119.

Mienis HK, 2001b. Mariene Mollusken uit het Oostelijk deel van de middellandse zee. 5. De eerste vondsten van *Canarium mutabilis. Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 323: 118.

Mienis HK, 2002. Mariene Mollusken uit het Oostelijk deel van de Middellandse Zee. Een tweede vondst van *Mactra lilacea*. *Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 325: 22.

Mienis HK, 2003a. Mariene mollusken uit het oostelijk deel van de Middelanse Zee 11. Een eerste vondst van *Cerithium columna* Sowerby, 1834. *Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 331: 31-32.

Mienis HK, 2003b. Marine molluscs from the Eastern Mediterranean 14. The first finds of *Octopus cyanea*. *Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 333: 88-89.

Mienis HK, 2003c. Marine mollusks from the Eastern Mediterranean 15. Invasion of cuttlebones of *Sepia pharaonis* along the coast of Israel. *Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 335: 127-129.

Mienis, HK, 2004a. New data concerning the presence of Lessepsian and other Indo-Pacific migrants among the molluscs in the Mediterranean Sea with emphasize on the situation in Israel. *Turkish Journal of Aquatic Life*, 2: 117-131.

Mienis HK, 2004b. An old find of *Retusa desgenettii* (Audouin, 1826) from the Bardawil Lagoon, Egypt. *Triton*, 10: 12.

Mienis HK, 2004c. Mariene mollusken uit het oostelijk deel van de Middellandse Zee 22. Een tweede vondst van *Vexillum (Pusia) depexum* in Israel. *Spirula – Correspondentieblad van de Nederlandse Malacologische Vereniging*, 339: 76-77.

Mienis HK, 2008. Monitoring the invasion of the Eastern Mediterranean by Lessepsian Migrants and other Indo-Pacific Molluscs. *Haasiana*, 4: 69-70.

Mienis HK, 2010. Exotic land and freshwater molluscs of Israel. *Haasiana*, 5: 66-68.

Mutaf BF, Akşit D, Gökoğlu M, 2007. Some marine gastropods first recorded from Antalya Bay, Turkey (the Mediterranean Sea). *JMBA2-Biodiversity Records*: 5151.

Nafaa MG, Fanos AM, Elganainy MA, 1991. Characteristics of waves off the Mediterranean coast of Egypt. *Journal of Coastal Research*, 7: 665-676.

Orme AR, 2005. Africa, coastal geomorphology. In: Schwartz ML, ed. *Encyclopedia of coastal science*. Springer-Verlag, The Netherlands: 9-20.

Ovalis P, Zenetos A, 2007. On the establishment of two more alien mollusca (*Chama aspersa* Reeve, 1846 and *Chama asperella* Lamarck, 1819) in the eastern Mediterranean. *Mediterranean Marine Science*, 8: 97-100.

Öztürk B, Poutiers JM, 2005. *Fulvia fragilis* (Bivalvia: Cardiidae): a lessepsian mollusc species from Izmir Bay

(Aegean Sea). *Journal of Marine Biological Association of the UK*, 85: 351-356.

Öztürk B, Can A, 2006. Indo-Pacific gastropod species in the Levantine and Aegean Seas. *Aquatic Invasions*, 1: 124-129.

Öztürk B, van Aartsen JJ, 2006. Indo-Pacific species in the Mediterranean. 5. *Chrysallida micronana* nom. nov. for *Chrysallida nana* (Hornung and Mermod, 1924) (Gastropoda: Pyramidellidae). *Aquatic Invasions*, 1: 241-244.

Özvarol Y, Gökoglu M, Karabacak GS, 2010. First report of *Hypselodoris infucata* (Rüppell & Leuckart, 1830) - (Mollusca, Opisthobrancia, Chromodorididae) in the Gulf of Antalya, Levantine coast of Turkey, Eastern Mediterranean. *Aquatic Invasions*, 5: 109-111.

Por FD, 1978. *Lessepsian migration. The influx of Red Sea Biota into the Mediterranean by Way of the Suez Canal*. Springer-Verlag, Heidelberg.

Por FD, Dimentman Ch, 2006. *Mare Nostrum. Neogene and anthropic natural history of the Mediterranean Basin, with emphasis on the Levant.* Pensoft Publishers, Sofia – Moscow.

Raitsos DE, Beaugrand G, Georgopoulos D, Zenetos A, Pancucci-Papadopoulou AM, Theocharis A, Papathanassiou E, 2010. Global climate change amplifies the entry of tropical species into the Eastern Mediterranean Sea. *Limnology Oceanography*, 55: 1478-1484.

Ralli-Tzelepi ZN, 1946. Contribution à l' étude conchyliologique du littoral de l' Attique (Grèce). Ph. D. Thesis, University of Athens.

Tillier L, Bavay A, 1905. Les mollusques testacés du Canal de Suez. *Bulletin de la Société Zoologique de France*, 30: 170-181.

Salman A, Katagan T, Von Boletzky S, 1999. New cephalopod molluscs in the Eastern Mediterranean: previously unnoted species or Lessepsian migrants? *Vie Milieu – Life and Environment*, 49: 11-17.

Settepassi F, 1967. *Atlante Malacologico: Molluschi Marini Viventi nel Mediterraneo I*. Museo di Zoologia del Comune di Roma.

Sharon Y, Benayahu Y, Mienis HK, 2005. First record of an exotic oyster: *Alectryonella crenulifera*, from the Mediterranean coast of Israel. *Triton*, 12: 5-6.

Tzomos T, 2007. Investigation of the progress of the lessepsian immigratory current, in respect of Mollusca and Pisces. M.Sc., Aristotle University of Thessaloniki.

Tzomos T, Kitsos M-S, Christodoulou M, Koukouras A, Eleftheriou A, 2007. Investigation of the evolution of the invasion and dispersion rates of the lessepsian Pisces in the Mediterranean. *Panhellenic Meeting on the Invasion of Alien Aquatic species in the Eastern Mediterranean, 5-6 November 2007, Heraklion Greece*: 7-8.

Tzomos T, Chartosia N, Christodoulou M, Kitsos M-S, 2010. New records and range expansion of lessepsian migrants in the Levantine and Aegean Seas. *Marine Biodiversity Records*, 3: e10.

van Aartsen JJ, 1987. European Pyramidellidae: 3. *Odostomia* and *Ondina*. *Bollettino Malacologico*, 23: 1-34.

van Aartsen JJ, 2002. Indo-Pacific migrants into the Mediterranean. 1. *Gibborissoa virgata* (Philippi, 1849). *La Conchiglia*, 34: 56-58.

van Aartsen JJ, 2006. Indo-Pacific migrants into the Mediterranean. 4. *Cerithidium diplax* (Watson, 1886) and *Cerithidium perparvulum* (Watson, 1886) (Gastropoda, Caenogastropoda). *Basteria*, 70: 33-39.

van Aartsen JJ, Barash A, Carrozza F, 1989. Addition to the knowledge of the Mediterranean mollusca of Israel and Sinai. *Bollettino Malacologico*, 25: 63-76.

van Aartsen JJ, Carrozza F, Lindner G, 1990. *Acteocina mucronata* (Philippi, 1849), a recent Red Sea immigrant species in the eastern Mediterranean. *Bollettino Malacologico*, 25: 285-298.

van Aartsen JJ, Recevik M, 1998. Altre due specie indopacifiche rinvenute nel Mediterraneo. *La Conchiglia*, 30: 13-15.

Yokes B, Rudman WB, 2004. Lessepsian opisthobranchs from southwestern coast of Turkey; five new records for Mediterranean. *Rapport de la Commission Internationale Exploration de la Mer Méditerranée*, 37: 557.

Zenetos A, Gofas S, Russo G, Templado J, 2003. *CIESM Atlas of Exotic Species in the Mediterranean, Molluscs*. In: Briand F, ed. CIESM Publishers, Monaco: 1-376.

Zenetos A, Koutsoubas D, Vardala-Theodorou E, 2005. Origin and vectors of introduction of exotic molluscs in Greek waters. *Belgian Journal of Zoology*, 13: 279-286.

Zenetos A, Ovalis P, Houart R, 2008. Eastward spread of *Ergalatax junionae* Houart, 2008 (Gastropoda, Mollusca), a recent alien species in the Mediterranean. *Journal of Biological Research-Thessaloniki*, 10: 221-223.

Zenetos A, Konstantinou F, Konstantinou G, 2009a. Towards homogenization of the Levantine alien biota: additions to the alien molluscan fauna along the Cypriot coast. *Marine Biodiversity Records*, 2: e156.

Zenetos A, Ovalis P, Kalogirou S, 2009b. Closing the gap: *Cerithium scabridum* Philippi, 1848 found in the South Aegean (Greece, Mediterranean Sea). *Journal of Biological Research-Thessaloniki*, 11: 107-110.

Zenetos A, Pancucci-Papadopoulou M-A, Zogaris S, Papastergiadou E, Vardakas L, Aligizaki K, Economou N A, 2009c. Aquatic alien species in Greece (2009): tracking sources, patterns and effects on the ecosystem. *Journal of Biological Research-Thessaloniki*, 12: 135-172.

Zenetos A, Ovalis P, Çeviker D, 2010. On some Indo-Pacific boring endolithic Bivalvia species introduced into the Mediterranean Sea with their host-spread of *Sphenia rueppelli* A. Adams, 1850. *Mediterranean Marine Science*, 11: 201-207.

Zenetos A, Katsanevakis S, Poursanidis D, Crocetta F, Damalas D, Apostolopoulos G, Gravili C, Vardala-Theodorou E, Malaquias M, 2011. Marine alien species in Greek Seas: Additions and amendments by 2010. *Mediterranean Marine Science*, 12: 95-120.